REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(LEAVE BLANK)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	14 April 1999	Journal Article

4. TITLE AND SUBTITLE

Can Digital Cameras Replace High Speed Film - A Joint Service Solution

5. FUNDING NUMBERS

6. AUTHOR(S)

Sean Pender

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Air Warfare Center Aircraft Division
22347 Cedar Point Road, Unit #6
Patuxent River, Maryland 20670-1161

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Naval Air Systems Command
47123 Buse Road, Unit IPT
Patuxent River, Maryland 20670-1547

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Flight-worthy, high-speed film cameras are used to evaluate stores separation characteristics. The evaluation of separation is a post mission process. If the compatibility engineer requires additional information in evaluating store separation characteristics, the recorded information must be further processed, or the test may have to be repeated. In addition, the settings and image quality cannot be confirmed before viewing the data. A digital imaging system referred to as the Airborne Separation Video (ASV) solves these issues. This paper will review the ASV, the advantages of this system, and system status.

14. SUBJECT TERMS

Digital cameras   Airborne Separation Video (ASV)

15. NUMBER OF PAGES

5

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

CAN DIGITAL CAMERAS REPLACE HIGH SPEED FILM-A JOINT SERVICE SOLUTION

Mr. Sean Pender
Naval Air Warfare Center - Aircraft Division
23048 Cedar Point Road
Building 3176
Patuxent River, MD, U.S.A.

Abstract

Flight-worthy, high speed film cameras are used to evaluate stores separation characteristics. The evaluation of separation is a post mission process. If the compatibility engineer requires additional information in evaluating store separation characteristics, the recorded information must be further processed, or the test may have to be repeated. In addition, the settings and image quality can not be confirmed before viewing the data.

A digital imaging system referred to as the Airborne Separation Video (ASV) solves these issues. This paper will review the ASV, the advantages of this system, and system status.

Introduction

The Airborne Separation Video (ASV) also referred to as the Advanced Digital Imaging System (ADIS), is a direct to digital multi-camera imaging system that is a form, fit (actually smaller in size than the film cameras), and function replacement of current high-speed film cameras currently carried on military aircraft. The ADIS provides: a preview capability that provides transmitted images of a store prior to release to ensure that image exposure and camera functions are acceptable; analysis of a store separation in near real-time via transmitted images; access of recorded store separation data immediately after flight; and reduction and possible elimination of the use of film and associated chemical disposal at government installations.

The ADIS program has a phased approach: Phase I provides the Near Term Test Capability (NTTC) which is a 512 x 512 pixel resolution camera (16 MM film replacement) with associated control equipment; Phase II provides the NTTC-V camera which is a 65% reduction in size, an increased frame rate of 1000 pictures per second (pps), and upgradable to a full color capability; follow on phases provide remote sensing capability which separates the Charge Coupled Device (CCD) sensor via twisted pair cable up to 30 feet from the camera body electronics; a Long Term Test Capability (LTTC) which is a 1024 x 1024 pixel resolution camera (35 MM film replacement) which will operate at 500 pps, in the same size as the NTTC-V; a standalone system for both airborne and ground tracking [the Multi-System Controller (MSC)]; and an Ultra-High Speed/Resolution Camera 4096 x 4096 pixel resolution operating at 400 pps, which would also allow for 512 x 512 pixel resolution at up to 20,000 fps. All configurations are fully ruggedized and provide real-time digital images for qualitative and post mission quantitative analysis. Figure 1 illustrates the ADIS configuration.

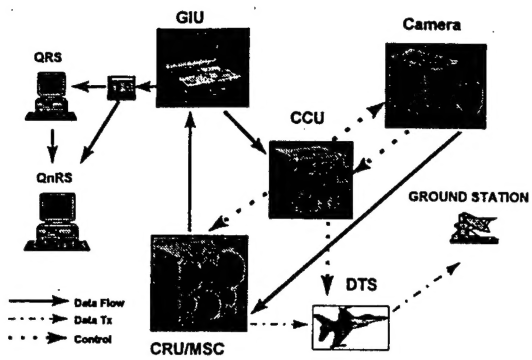

Figure 1 ADIS Configuration

Specification Development

The tri-service community, consisting of representatives from the U.S. Navy, U.S. Air Force and U.S. Army defined the baseline configuration. As the program has expanded in scope a survey was conducted among Range Commander's Council - Optical Systems Group (RCC-OSG) members to better identify ground based and follow on user requirements. Responses were collected, prioritized and incorporated in the A-Specification, which has been updated as needed to meet changing requirements.

System Issues

Based on the A-Specification requirements, a system was designed, built and tested that resolved many unique issues associated with an advanced digital system.

Central Control

As today's avionics/weapon systems become more advanced, a requirement for a large number of cameras to be installed to monitor tests at various distances from the event. Currently, cameras are mounted within a pod, out in the free air stream on a wing tip, in enclosures or pylons, or on a ground based pedestal. In each instance there could be up to thirty cameras involved. To ensure accuracy and synchronization of data and to meet the limited space requirements a single central control unit was needed. The ADIS was designed with the capability to control multiple streams of daisy chained cameras from one central control system. The controller provides the single interface to program, initiate, terminate, and record camera functions. Upon reception of a trigger signal each camera may record images for a preprogrammed time both before and after signal reception. Unlike film cameras, the system does not have to be manually initiated by the user prior to the event.

Sensitivity & Exposure Control

The ADIS was required to function in lighting conditions that ranged from dusk to full sunlight. In addition to this large variation (sensitivity), the change from one millisecond to the next can be quite large. To meet this requirement a frame to frame electronic shutter was designed to automatically control the exposure time.

Memory Storage

To store the images in digital format requires a high-speed, high-capacity memory capability. To resolve this issue the images are stored in volatile memory within the camera and then downloaded to non-volatile memory in the recorder unit or to a data communication system for transmission (with or without encryption). The recorder memory was designed as a modular unit that can be replaced as technology advancements allow for increased data byte storage.

Environmental

Each component of the ADIS was required to meet the operational and storage environment requirements of all military aircraft. This included: Altitude/Temperature, Salt/Fog, Humidity, Shock, Temperature Shock, Dust, Acceleration, Vibration, AC and DC Power input and Electromagnetic Interference (EMI) with no degradation of system performance. This ruggedization was accomplished using Commercial-Off-The-Shelf (COTS) equipment as much as possible. Including cost effective

RAM modules, data cables, power supplies and design electronics.

Miniaturization

Early in the program a need for a smaller version of the NTTC camera was defined. The miniaturized version (NTTC-V) was designed to fit in a fairing. This was later expanded to include installation in a pod. While the pod provides a more benign environment than the free stream installation, it is a system requirement that all configuration items be as interchangeable as feasible. Therefore, the miniaturized version had to be as ruggedized as the larger camera.

Real-Time Preview Mode

The expense of conducting test and evaluation on aircraft are often compounded by poor lighting conditions, incorrect camera settings, camera system malfunctions, fogged lenses, etc., which produce insufficient data and necessitate re-testing of a data point. The ADIS has a preview mode that allows the user to view the transmitted images in real-time and see what the camera is actually seeing. The images are transmitted at 30 pps to the receiving station. Built-In Tests (BITs) are run in the background and all errors are displayed to the user. The preview mode ensures that the test conditions have been met and the camera is functioning properly prior to performing the test.

Real-time Modifications

Since the ADIS has the capability to preview the mission and allow the test engineer to identify anomalies prior to weapon separation. A user interface was designed to allow the user to optimize all system settings prior to continuing with the test.

Data Transmission System (DTS)

The DTS accepts digital images from the CRU and uses a video compression system which adheres to IRIG Standard 210 to compress, encrypt and transmit these images to the ground over a non specific frequency with either 5 or 10 MHz bandwidth where they are decoded and displayed.

Encryption

It is a requirement during the majority of tests on military facilities to encrypt weapons system data. All ADIS image data can be encrypted for transmission then decrypted upon reception with no degradation in resolution. This permits telemetry in free air space without fear of compromising the test mission (the ADIS also will work without encryption).

Resolution

Converting digital data to analog images results in degradation in resolution and causes delay in data analysis. Therefore, the ADIS requirement is to store the images digitally at all times for post flight qualitative and quantitative analysis.

Remote Sensing

In many test configurations the location of the sensor can be a very small area. To meet this requirement a remote sensor configuration of the camera was developed. The remote sensor has the head, or sensor portion, of the camera as a separate entity that may be located up to thirty (30) feet away from body, or electronic portion of the camera. This is ideal for installation on low radar cross section aircraft platforms. The design is a subset of the NTTC-V camera version.

Data Merge

So that the ADIS image data could be merged to that of other systems used during testing the ADIS digital data images are time-tagged at the time of capture. This permits multiple asynchronous sources to be merged for qualitative and quantitative analysis.

Standalone Capability

During the development of ADIS it became quickly apparent that there was a requirement for

a standalone system for both airborne and ground based units. In the airborne standalone configuration, the ADIS can be used even when the aircraft has not been modified with cabling by utilizing an instrumentation pod connected to the aircraft for power and trigger/event signals only. In the ground configuration the ADIS is installed on tracking pedestals. In both cases, the system operates autonomously as preprogrammed by the user. As with the other configurations, the digital images are available in near or real-time for analysis.

Testing

In performing, ADIS system acceptance testing, both static and dynamic component and system level tests were conducted.

Laboratory Testing

Laboratory tests included performing environmental testing to ensure compliance with all environmental and EMI requirements and First Article Testing (FAT) tests were performed to prove that ADIS met all functional and performance requirements as delineated in the A-Specification. One of the FAT compliance tests was to ensure that cameras met system resolution requirements. Comparing the Contrast Transfer Function (CTF) and Modulation Transfer Function (MTF) to that of 16 mm film. Results show that the ADIS images provided consistently comparible performance with digitized 16 mm film and that there is a superiority in preserving high spatial frequency (fine) detail in the ADIS images.

Ground Test

Upon successful completion of the environmental testing and FAT, the ADIS was delivered to the Government for testing. Ground tests included static and dynamic tests. A series of eight individual bomb drop tests were performed. The bomb was surveyed using traditional theodolite survey equipment at the beginning and terminal locations to ensure quality control information. Truth data was provided by a control camera, which remained at a fixed distance from the target. A set of 16 mm film and ADIS cameras were positioned eight (8) feet from the bomb drop area and moved further away with each test, eventually reaching a maximum of thirty-five (35) feet from the target area. It was anticipated that the digital imaging accuracy would equal that of the film system at closer range and then degrade as the distance increased. Results of the quantitative data reduction system (QnRS) showed the NTTC digital data compared favorably with the 16 mm film data.

Flight Test

Rotary Wing

A flight test on a rotary wing platform was successfully performed to confirm aircraft compatibility and environmental and EMI performance in an operational environment. More rotary wing tests are scheduled to confirm the capability to function with the higher vibration requirements of these platforms in real world scenarios.

Fixed Wing

A Navy test aircraft had the ADIS wiring installed and completed first flight on 26 March 1998. The purpose of the flight was to release two (2) bombs, record the drop with three ADIS digital cameras and three film cameras for post flight comparison purposes. All of the ADIS NTTC cameras and the film cameras mounted on the aircraft captured detailed images of the ordnance drops. The ADIS camera images were then compared to the film camera images. Accuracy results were consistent with the ground bomb test results and continued to show that the ADIS is an acceptable replacement to the film.

The second flight consisted of only one NTTC camera (on the aircraft tail) and three film cameras (left wing, right wing, and tail). During flight, two film cameras failed while the NTTC camera successfully captured the digital images for post flight qualitative and quantitative analysis.

Additional flight tests were successfully conducted on both Navy and Air Force aircraft recording various store separations.

Mission Support

After completing the initial testing phase, the ADIS has been used to provide mission support for aircraft and ordnance acceptance testing. The ADIS is scheduled to be used to evaluate arrestment certification testing during aircraft carrier suitability testing. Additionally, the system was used for ground testing of bomb drops for a test that consisted of 600 test drops. The digital camera provides a means of instant review of a test event whereas with regular film, it could be a day or more before film is ready to be read. This feature is extremely important. The digital system also keeps film related costs down.

Future Plans

The program will continue with the development of the LTTC camera with its 1024 x 1024 pixel resolution to be comparable to 35 mm film cameras, followed by the Ultra High Speed/Resolution (4096 x 4096 pixel resolution) to be comparable to 70 mm film cameras.

In addition to camera improvements a digital telemetry system is being developed. This capability will allow the recorded images to be sent to the ground and feed to the analysis tool prior to the aircraft landing. This will help to speed up the analysis process.

Conclusion

Advancements in CCD technology, digital memory capacity both DRAM and hard drive, and computer processing speed are making digital imaging an acceptable, cost-effective, reliable, and workable solution to experimental test and evaluation requirements.

Biography

Mr. Pender obtained his Bachelor of Engineering degree in Electronics & Computer Engineering from George Mason University.

Mr. Pender is the Program Manager of the Advanced Digital Imaging System (ADIS) currently being developed and tested at the Naval Air Warfare Center - Aircraft Division, Patuxent River, Maryland, U.S.A. Past experience includes Optics development, Global Positioning System (GPS) Surveying, Laser Safety and Development as well as teaching Digital Communications Theory in his spare time at the local community college.

Mr. Pender is an active member of the International Test and Evaluation Association (ITEA).